

## A note on the taxonomy and distribution of *Triops* Schrank (Crustacea: Branchiopoda: Notostraca) in southern Africa

by

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### ABSTRACT

It is currently accepted that Notostraca are represented in southern Africa by a single species, *Triops granarius* (Lucas). The collection of an exceptionally large female *Triops* (total length 57.7 mm) from the northern Cape in 1988 prompted a re-examination of *Triops* material. Much variation (both intra- and inter-population) in the key taxonomic character of telsonic spine arrangement, was evident. Examination of the type material of *Apus* (*T.*) *ovamboensis* Barnard, confirmed that *ovamboensis* is a synonym of *T. cancriformis* (Bosc), establishing that both *T. granarius* and *T. cancriformis* occur in southern Africa.

The large specimen shares some characters with *Apus* (*T.*) *trachyaspis* Sars (a synonym of *T. granarius*). A number of samples from north-eastern Natal could not be identified, even if the criteria for *T. granarius* were broadened. The exceptional size of the northern Cape specimen could be a result of episodic flooding in March 1988, which may have influenced the hatching of a genetically distinct population of *Triops* or simply provided a habitat conducive to exceptional growth in *T. granarius*. There is a need for more detailed studies on the systematics of *Triops*, and on the morphological variation in key taxonomic characters. Habitat data and specimen measurements are presented for seventeen new localities.

### INTRODUCTION

*Triops* Schrank has been known since 1732 when it was characterised by Frisch from Lund in Sweden. In 1735, Linnaeus, in the first edition of *Systema Naturae*, referred to Frisch's description and named the animal *Monoculus Apus*, an inappropriate name because *Triops* has two eyes and many locomotory appendages (Fox 1949).

Barnard (1929) recognised four species of *Triops* from southern Africa: *numidicus* (Grube), *namaquensis* (Richters), *sudanicus* (Braem), and *cancriformis* (Bosc). These were united by Longhurst (1955) into one species, *T. granarius* (Lucas), as Barnard's (1929) characters of carapace shape and number of apodal somites were considered to be too variable. Longhurst recognised only four species worldwide; *cancriformis*, *granarius*, *longicaudatus* (LeConte) and *australiensis* (Spencer & Hall). He considered that the arrangement of spines on the telson of the adult is of the 'greatest systematic importance' in separating species of *Triops*. Rayner & Bowland (1985) found no reason to contradict Longhurst's opinion regarding sub-Saharan *Triops* species, although they examined material from two localities only. Meintjes *et al.* (1994) described morphological variation in a population from Bain's Vlei in the Orange Free State, but did not include data on the telsonic spines, although they

did state that the 'phylogenetic structures used by Longhurst in his key are fixed in *T. granarius* and did not vary in the Bain's Vlei population'. The other characters used in Longhurst's key were the presence of a second maxilla and the armature of the apodal somites.

A female was collected from a population of exceptionally large-sized animals in March 1988, from a pan (a natural, episodically-filled ephemeral water body) in the northern Cape. In an attempt to identify this specimen, it was compared with *Triops* material from a wide range of localities in southern Africa. Only the two characters most highly weighted by Longhurst (armature of telson and of apodal somites) were examined for this study, since other morphological characters are supposedly too variable to be taxonomically significant (Longhurst 1955; Meintjes *et al.* 1994).

Meintjes *et al.* (1994) plotted the distribution of *Triops* in southern Africa using Barnard's records as well as those from more recent museum collections. Localities from most of the eastern part of southern Africa were not included. Rayner & Bowland (1985) published the only record of *T. granarius* in Natal, from Umfolozi Game Reserve. Subsequently, this species has been found to have a much wider distribution.

This study presents a list of habitat and specimen data, an updated distribution map for *Triops* in southern Africa, and details and illustrations of the variation in telsonic spines and apodal somite armature of *Triops* specimens examined.

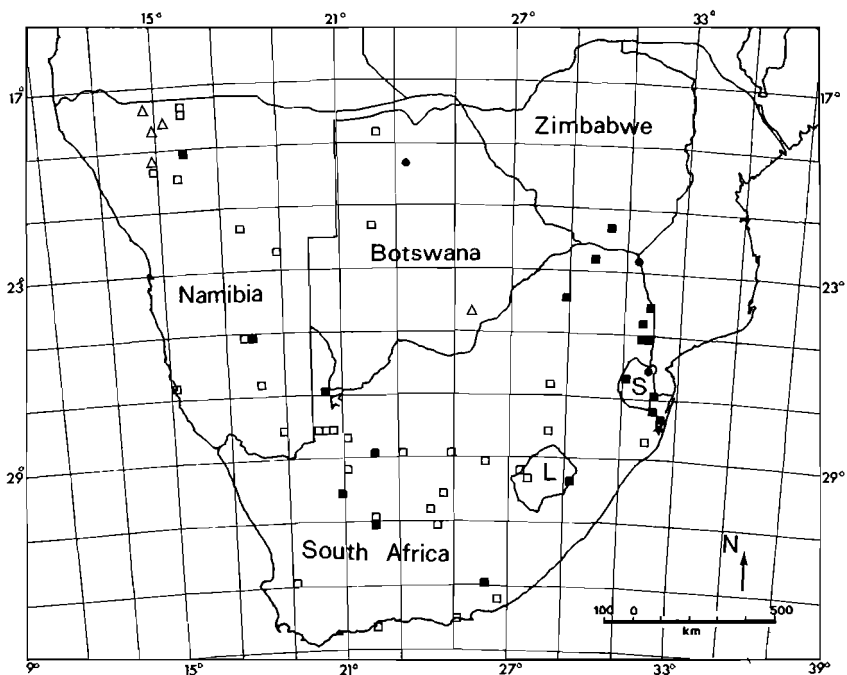


Fig. 1. Map of southern Africa showing *Triops* collection localities. *Triops granarius*: □ = records from Barnard (1924 1929 1935) and SAM material; ■ = previously unpublished localities; ● = records from BMNH and ZNM. *Triops cancriformis* = △; *Triops* sp. indet. = ★. [Arrow indicates Koppieskraal Pan; S = Swaziland, L = Lesotho.]

## MATERIALS AND METHODS

*Triops* specimens were collected with aquarium nets and preserved in 70 % ethanol. Measurements of median carapace length (mcl) and total length (tl) (excluding caudal furca) were made with Vernier callipers and they are presented as a range for each measurement. Illustrations of telsonic somites were made using a Wild dissecting microscope and drawing tube. Most of the South African Museum (SAM) material had dried out, and details of only some of these specimens are included. A set of specimens from the Zimbabwe National Museum, Bulawayo (ZNM), was also examined and a record from the British Museum of Natural History (BMNH) is presented on Fig. 1. Material collected by the authors will be deposited in the Albany Museum, Grahamstown (AM).

## MATERIAL EXAMINED

*Triops* sp. indet.

SOUTH AFRICA: *Natal*: AM LEN 218A, 4 ♂ (mcl = 6.0–8.1 mm; tl = 13.0–17.1 mm); small rainpool (approximately 6 X 3 m), unvegetated with black-stained water; False Bay Park (27°58'46"S:32°21'16"E); pH – 6.4; temperature – 24°C; conductivity – 240 µS/cm; coll. M. Hamer, K. Martens & M. Coke, 26 October 1994. AM LEN 220A, 1 ♀ (mcl = 16.2 mm; tl = 28.0 mm); rainpool, Godlogodlwane area, near Msinyeni pan, Makatini Flats (27°15'30" S:32°09'30"E); coll. T. Pike, 5 November 1994. AM LEN 221A, 1 ♀ (mcl = 17.9 mm; tl = 29.5 mm); clear pool (approximately 30–90 mm deep), with emerging and submerged macrophytes; pool part of feeder stream to Nsumu Pan, Mkuze Game Reserve (27°39'24"S:32°18'07"E); pH – 7.6; temperature – 23°C; conductivity – 302 µS/cm; coll. M. Hamer, M. Coke & K. Martens, 28 October 1994.

*Triops granarius* (Lucas)

SOUTH AFRICA: *Cape*: AM LEN 175A, 1 ♀ (mcl = 30.0 mm; tl = 57.7 mm); turbid roadside ditch (200 X 3 m), 20 cm deep, beside R31 through Koppieskraal Pan, between Aroab and Kalahari Gemsbok Park (26°55'S:20°20'E); coll. J. D. Pickstone and Michaelhouse schoolboys, 27 March 1988. AM LEN 176A, 1 ♂ (mcl = 7.1 mm; tl = 14.8 mm); 7 days old, hatched from sediment from above locality; coll. M. Hamer, 22 December 1992. AM LEN 79C, 5 ♂ (mcl = 9.0–14.9 mm; tl = 24.0–34.5 mm); turbid, sparsely vegetated pool (10 X 15 m), approximately 15 cm deep; 10 km S. Carnavon on road to Loxton (31°10'S:22°08'E); coll. M. Hamer, 16 February 1990. AM LEN 130D, 6 ♂ (mcl = 10.5–13.0 mm; tl = 24.0–28.2 mm), 3 ♀ (mcl = 9.5–11.8 mm; tl = 20.5–27.8 mm); unvegetated, turbid pool (3 X 5 m) in dried out river bed, Grootvloer Pan, 98 km S. Kenhardt (30°06'S:20°36'E); coll. M. Hamer, 19 December 1992. AM LEN 80C, 16 ♂ (mcl = 10.8–13.5 mm; tl = 21.0–29.5 mm), 10 ♀ (mcl = 10.5–14.5 mm; tl = 19.8–29.2 mm); 4 km E. Groblershoop (28°55'S:22°05'E); coll. O. Wirminghaus, 8 April 1990. SAM 11608, 2 ♂ (mcl = 10.0–11.5 mm; tl = 28.0–30.0 mm), 1 ♀ (mcl = 11.2 mm; tl = 21.0 mm); Mossel Bay, date and coll. unknown. *Natal*: AM LEN 219A, 5 ♀ (mcl = 12.0–16.5 mm; tl = 23.8–30.4 mm); shallow, muddy and grassy rainpool, Makatini Flats (27°24'21"S:32°11'08"E); pH – 7.8; temperature – 23°C; conductivity – 328 µS/cm;

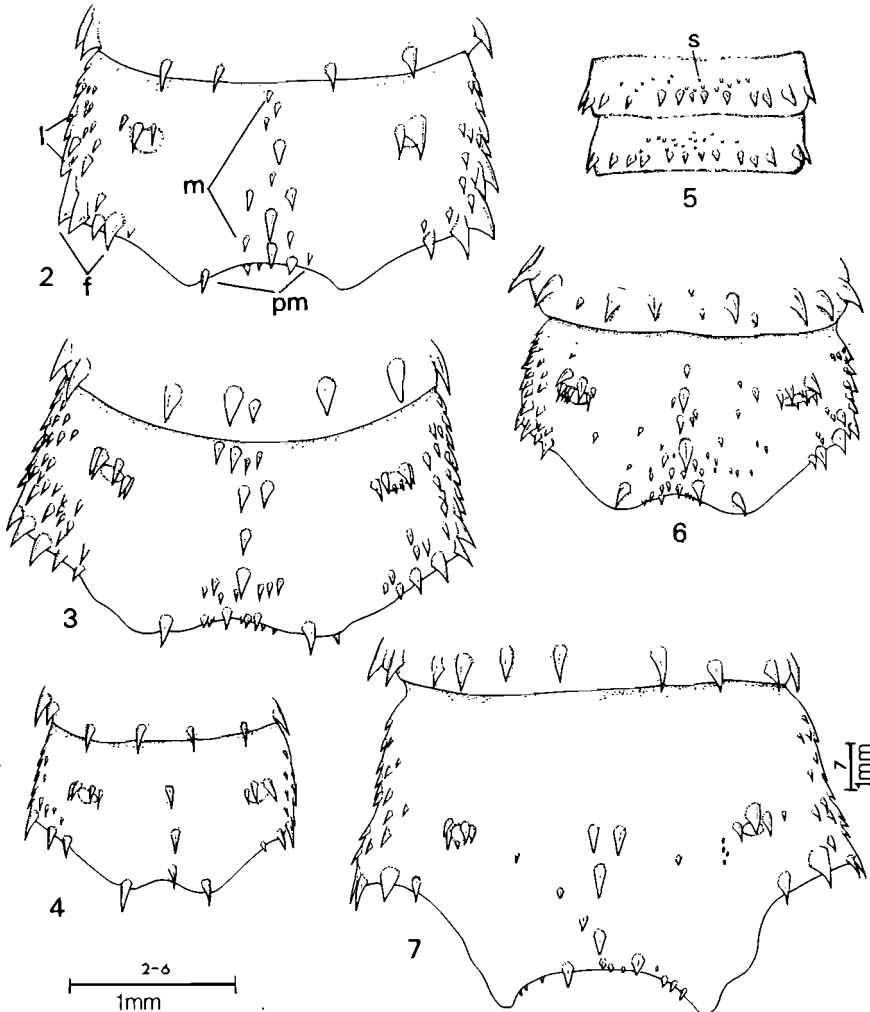
coll. M. Hamer, K. Martens & M. Coke, 27 October 1994. AM LEN 178A, 3 ♂ (mcl = 4.8–7.0 mm; tl = 11.0–14.5 mm); small (3 X 4 m), unvegetated, turbid and shallow (approximately 10 cm) animal wallow, Umfolozi Game Reserve (28°20'S:31°50'E); coll. M. Hamer, September 1985. *Transvaal*: AM LEN 75B, 3 ♀ (mcl = 7.0–9.5 mm; tl = 15.6–18.0 mm); turbid rhino wallow, Mala Mala Game Reserve (24°45'S:31°30'E); coll. W. Taylor, 25 June 1989. AM LEN 117C, 6 ♂ (mcl = 6.2–9.5 mm; tl = 14.5–20.5 mm), 2 ♀ (mcl = 7.5–9.0 mm; tl = 13.5–20.0 mm); small unvegetated, or sparsely grassed game wallows, S of Skukuza, Kruger National Park (25°03'S:31°38'E); coll. A. & J. Bowland, 14 October 1990. AM LEN 99A, 5 ♂ (mcl = 4.8–5.8 mm; tl = 9.2–12.0 mm), 6 ♀ (mcl = 4.6–6.0 mm; tl = 8.5–11.9 mm); large (20 X 30 m), 30 cm deep pan with clear water and dense *Elodea*-type vegetation, near Pumbe picket fence, Kruger National Park (24°07'S:31°53'E); coll. M. Hamer, 26 October 1990. AM LEN 134E, 1 ♂ (mcl = 13.8 mm; tl = 28.5 mm); turbid pan (30 X 40 m), Mopane, 35 km S. Beit Bridge (22°36'S:29°52'E); coll. O. Wirminghaus, 31 December 1992. SWAZILAND: AM LEN 126B, 1 ♂ (mcl = 6.0 mm; tl = 13.0 mm), 1 ♀ (mcl = 7.2 mm; tl = 15.0 mm); Hlane Game Reserve (26°20'S:20°00'E); coll. T. Konstant, 1990. LESOTHO: AM LEN 207A, 16 ♂ (mcl = 7.0–9.8 mm; tl = 16.0–23.5 mm); 6 ♀ (mcl = 7.0–9.5; tl = 14.0–20.8 mm); temporary pool (3 X 15 m), densely vegetated with *Limosella inflata*, Sani plateau, Drakensberg (29°34'34"S:29°17'56"E, ± 2900 m); pH – 7.6; temperature – 14.1°C; coll. M. Hamer & K. Martens, 23 March 1995. ZIMBABWE: AM LEN 137D, 3 ♂ (mcl = 13.0–15.0 mm; tl = 23.0–30.5 mm), 4 ♀ (mcl = 13.2–15.8 mm; tl = 23.2–25.9 mm); small (8 X 8 m), shallow, turbid pool, 33 km S. Bubi River (21°45'S:30°28'E); coll. O. Wirminghaus, 31 December 1992. NAMIBIA: AM LEN 77C, 4 ♂, 1 ♀ (no measurements, specimens in poor condition); pool 65 km S. Mariental (25°10'S:17°50'E); coll. O. Wirminghaus, 7 April 1990. AM LEN 150B, 1 ♂ (mcl = 5.0 mm; tl = 9.0 mm); Leeubron, Etosha National Park (19°03'S:15°48'E); coll. A. Bowland, 22 November 1985. BOTSWANA: ZNM Cr/4, 27 specimens, most with mcl < 5 mm; Maun, XaXaba (19°59'S:23°25'E); coll. J. L. Minshall, 29 November 1983.

*Triops granarius* (Lucas) [*trachyaspis* form]

SOUTH AFRICA: *Cape*: Holotype ♀ (SAM A1494) completely dried out. SAM A1482 (paratypes of *Apus trachyaspis*), 1 ♂ (mcl = 20.0 mm), 1 ♀ (mcl = 21.5 mm); both specimens with damaged apodal somites; Port Elizabeth (type locality) (34°S:25°E); coll. J. L. Drege, date unknown.

*Triops cancriformis* (Bosc)

NAMIBIA: SAM A5997 (Syntypes of *Apus* (*T.*) *ovamboensis*), 3 ♂ (mcl = 8.8–10.8 mm; tl = 19.8–25.0 mm), 10 ♀ (mcl = 11.2–16.0 mm; tl = 15.0–27.2 mm); Onolongo, Ovamboland (18°31'S:15°36'E); coll. K. H. Barnard, 1923. SAM A6749, 1 ♂ (mcl = 10.5 mm; tl = 19.0 mm), 5 ♀ (mcl = 8.8–11.0 mm; tl = 16.0–20.8 mm); between Kamanyab and Choabendus, Ovamboland (19°40'S:14°50'E); coll. K. H. Barnard, 1926. SAM A5996, 2 ♂ (mcl = 13.0–13.5 mm; tl = 24.5–25.8 mm), 3 ♀ (mcl = 8.2–14.8 mm; tl = 13.0–25.0 mm); Uwuthija, Ovamboland; coll. K. H. Barnard, 1926.



Figs 2-7. *Triops granarius*, variation in key characters in specimens from different localities (provenance in parentheses). 2. Dorsal surface of telson (Mossel Bay) (SAM A11608): l = lateral spines, m = median spines, pm = posterior marginal spines, f = furcal spines. 3. Dorsal surface of telson (Zimbabwe) (AM LEN 137D). 4. Dorsal surface of telson (Mala Mala) (AM LEN 75B). 5. Ventral surface of apodal somites (Mala Mala) (AM LEN 75B), showing supernumeraries (s). 6. Telson of 'trachyaspis' form of *T. granarius* (Grahamstown, uncatalogued material, SAM). 7. Dorsal surface of female telson (Koppieskraal) (AM LEN 175A).

## RESULTS AND DISCUSSION

### Distribution

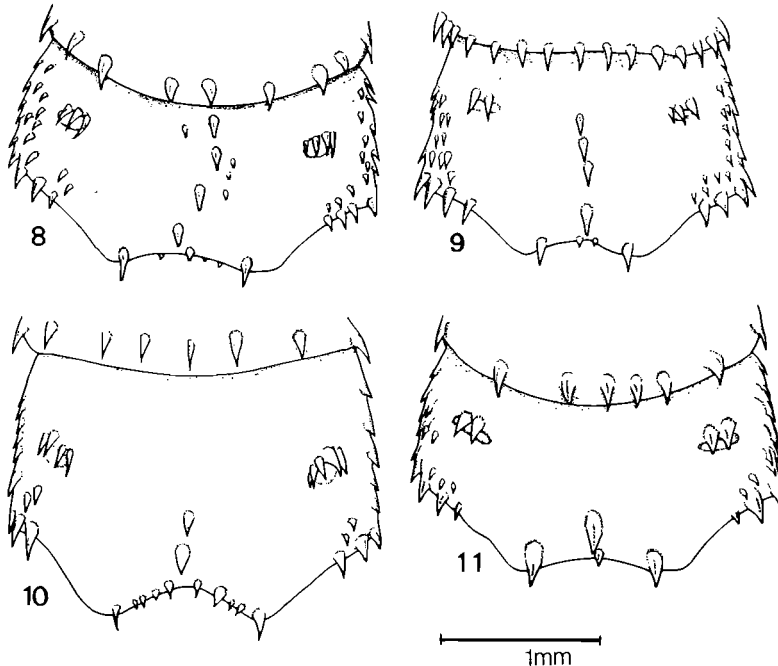
Based on previously published localities and new records, the known distribution of *Triops* in southern Africa is plotted in Fig. 1. The temporary pools of large parts of Zimbabwe, Botswana and the northern parts of South Africa have not been investigated and the actual distribution is probably even wider. Habitats from which *Triops* has been collected include turbid, unvegetated game wallows and densely

vegetated, high altitude pools (in Lesotho). The southern parts of Natal appear to lack suitable habitats for branchiopods and *Triops* has not been collected from this area, nor from the sandstone rockpools and tarns in the Lower Drakensberg. There appears to be little correlation between *Triops* distribution and the 500 mm isohyet, as suggested by Meintjes *et al.* (1994).

#### Character variation and species delimitation

Variation in the arrangement, number and size of telsonic spines was evident in specimens examined. A number of small, scattered spines in the mid-dorsal region (median spines), numerous small furcal spines, and small posterior marginals are typical of *T. granarius* (Longhurst 1955). Figures 2 and 3 illustrate this arrangement of spines, but the furcal spines are the same size or larger than the posterior marginals and most of the median spines. The reduced number of larger median spines (Fig. 4) also falls within the limits for *T. granarius*, since Longhurst did state that it is not the number of telsonic spines but rather their arrangement which is taxonomically important. The two larger posterior marginal spines in Figs 3 & 4 do not concur with Longhurst's description. The presence of supernumeraries – small, scattered projections on the ventral surface of the apodal somites (Fig. 5) – is an important characteristic of *T. granarius*, and one used to separate this species from *T. cancriformis* in Longhurst's key. The specimens illustrated in Figs 2–7 all have supernumeraries.

Variation in telson spine arrangement was also evident within many populations



Figs 8–11. *Triops granarius*, variation in telsonic spines (Grootvloer Pan specimens) (AM LEN 130D).

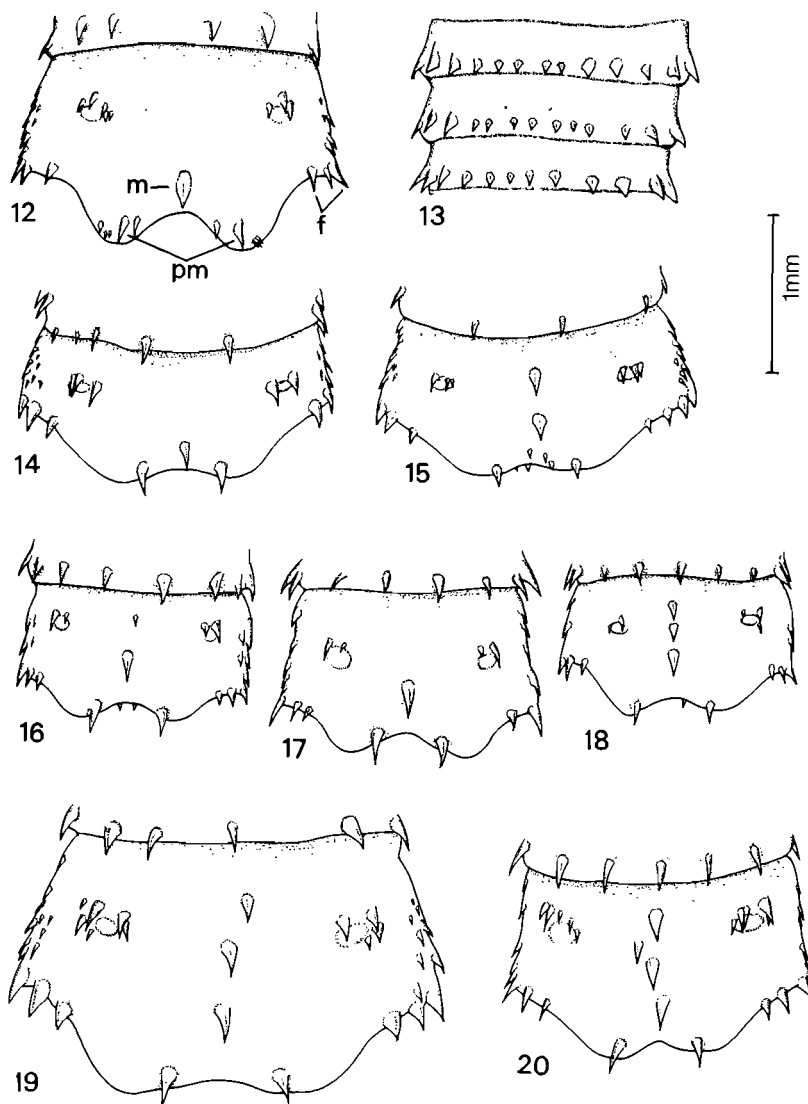
and was not related to sex or size of specimens. An example of the extent of this variation is illustrated in Figs 8–11. All four specimens would key out as *T. granarius* according to Longhurst, but the arrangement of the median spines (Figs 10 & 11), and the posterior marginal spines (Fig. 11), are not as described for this species. As the key character for distinguishing species of *Triops* is so variable within and between populations, there is some doubt about its value and about the assumption that there is only a single species in southern Africa.

*Apus trachyaspis* Sars from the Port Elizabeth area, was recognised by Longhurst as *T. granarius*; its name refers to the covering of fine spines on the carapace. The telson of the *A. trachyaspis* specimens confirms their status as a form of *T. granarius* according to Longhurst's definition (Fig. 6). The fine carapace spines were found by Longhurst not to be a specific character and to occur in *T. longicaudatus* as well as in *T. granarius*. Such forms of *granarius* are referred to as the '*trachyaspis*' form. The telson of the exceptionally large, Koppieskraal specimen, is similar to that of these specimens, but fewer median spines are present (Fig. 7).

Longhurst described the telson of *T. cancriformis* as having 1–4 large median spines arranged in a single row, posterior marginals small and fine and with few large furcal spines. Few spines are present on the lateral surface of the telson (Fig. 12), and the furca is generally long. An important character of this species is the absence of supernumeraries on the ventral surface of the apodal somites (Fig. 13). Barnard's syntypes of *A. ovamboensis* (Fig. 12) fit Longhurst's description of *T. cancriformis*. Longhurst, however, synonymised *Apus ovamboensis* with *T. granarius*, although Barnard had stated that he thought *A. ovamboensis* should be synonymised with *A. cancriformis*. Three other samples collected from Ovamboland (SAM A5998, A5999, A6000) were identified as *A. ovamboensis* by Barnard. A further two samples from Ovamboland (SAM A6749; SAM A5996) fit the description for *T. cancriformis* (Figs 14–15), but Barnard identified these as *A. numidicus*.

Barnard (1935) also recorded the collection of 45 specimens of *T. cancriformis* from Kanke Pan, 90 miles W of Molepole in Botswana (Fig. 1), by the Vernay Lang Kalahari Expedition, on 19 March 1930. Longhurst considered this material to be *T. granarius*. These specimens are missing from the Transvaal Museum collection. Meintjes (1992) confirmed the identity of other Transvaal Museum material from southern Ovamboland, collected in 1937, as *T. cancriformis*, establishing seven records of *T. cancriformis* from southern Africa.

Specimens from three localities in north-eastern Natal (False Bay Park, Mkuze Game Reserve, Makatini Flats) lack distinct supernumeraries on the apodal somites and have unusual telsonic spines (Figs 16–20). Two large posterior marginal spines are present in all specimens, and the median spines are consistently larger and fewer than in other *Triops* material examined. A small number of spines are present on the lateral surface of the telson. In all characters, except the posterior marginal spines, the north-eastern Natal specimens fit the description of *T. cancriformis*. Most populations of *Triops* from other localities in north-eastern Natal had similar telsonic spine arrangements, but supernumeraries were present on the apodal somites. There was a large amount of variation in the abundance of supernumeraries, with the number ranging from two to three barely visible projections to over thirty distinct supernumeraries per somite.



Figs 12–20. *Triops* species (provenance in parentheses). 12. Syntype of *A. ovamboensis* (= *T. cancriformis*) (SAM A5997), dorsal view of telson: f = furcal spines, m = median spine, pm = posterior marginal spines. 13. Ventral surface of apodal somites showing absence of supernumeraries. 14. Dorsal surface of telson (Uwuthijia) (SAM A5996). 15. Dorsal surface of telson (betw. Kamanyab and Choabendus) (SAM A6749). 16–20. *Triops* indet. 16–18. Dorsal view of telsons (pool in False Bay Park). 19. Dorsal view of telson (Makatini Flats) (AM LEN 220A). 20. Dorsal view of telson (Mkuze Game Reserve) (AM LEN 221A).

The difficulty of identifying *Triops* material again raised the question of whether Barnard (1929) was correct in recognising four species in southern Africa. Material examined from museums and from the field confirmed that *A. numidicus* is a synonym of *T. granarius*. Accepting that *A. ovamboensis* is a synonym of *T.*



*cancriformis*, leaves two nominal species (*A. sudanicus* and *A. namaquensis*) unaccounted for. Barnard (1929) made a strong point that the carapace of *A. namaquensis* is round, while in the other three species it is oval. The large unidentified specimen listed above also has a round carapace (Fig. 21). In the light of Longhurst's low weighting of carapace shape, however, the synonymy of *A. namaquensis* with *T. granarius* appears valid. Also, Richters (1886) described *A. namaquensis* from one male only, without illustrations. Barnard (1929) stated that he had not seen any authentic specimens of *A. sudanicus*, and identified this species on the number of apodal somites. Longhurst synonymised *sudanicus* with *T. granarius*, a decision supported by Brauer's (1877) illustration of the telson of *sudanicus*.

The large amount of variation in telsonic spine arrangement, and the difference in this character between the specimens examined and Longhurst's descriptions for *Triops* species, indicates either that this is not always a useful character, or that species limits require redefinition. Although Longhurst did state that there was much variation in the number of telsonic spines, he was confident that the arrangement of these was constant. In southern African *Triops* there is definitely more than one pattern of telsonic spines.



Fig. 21. *Triops granarius*: Comparison of large Koppieskraal Pan female with rounded carapace, and form with oval carapace and of average size. Scale line = 1 mm.

### Episodic flooding and *Triops* size

The population of large *Triops* was present in the Koppieskraal Pan ditch subsequent to severe flooding in the Orange River basin of the Northern Cape in 1988. The episodic Molopo River, which has a confluence with its tributary, the Kuruman River, 50 km E. of Koppieskraal Pan, and from where water drainage in the area rises, had 100–200 % normal rainfall in February 1988 and in March 200–300 % (du Plessis *et al.* 1989). It is possible that the Koppieskraal population represents a species adapted to hatch only during episodic flood events. Meintjes (1992) collected specimens from 13 localities in South Africa and Namibia. The largest specimens were from Bain's Vlei in the Orange Free State and were collected during the March 1988 episodic flooding of the region. Specimens were about twice the usual size, and Meintjes (1992) could find no previous or subsequent records of such large specimens from Bain's Vlei. Meintjes *et al.* (1994) suggested that the length of inundation and abundant food may have enabled the specimens to grow to larger than usual size.

### Summary

In summary, two species, *T. cancriformis* and *T. granarius*, are confirmed from southern Africa. In order to accommodate the large amount of variation observed, *T. granarius* should be redefined as follows: distinct supernumeraries on ventral surface of apodal somites, but these projections may vary from very few (less than five per somite) to many in number, median spines range in number from one to more than ten and in size from small to large, and arranged in a row or scattered in median region of telson; posterior marginal spines varying in size, two to many. The large Koppieskraal Pan female and the male hatched from Pan sediment would be allocated to *T. granarius* if this definition was accepted. The False Bay Park specimens and those illustrated (Figs 19 & 20) would remain unidentified.

Fryer (1988) suggested that widely distributed species of Notostraca are perhaps broken up into more genetic populations than has been supposed or may even consist of several cryptic species. He stated that this is not unexpected in such an ancient group in which dispersal is less easily achieved than is considered to be the case. Additional material and molecular studies on the sub-Saharan species of *Triops* may clarify this. The systematics of *Triops* has puzzled scientists for 260 years, and the unpredictability of the habitat of these animals continues to hamper the collection of material, and therefore, detailed systematic studies.

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